SENSORS & CONTROLS

Project Fact Sheet

Diode Laser Sensor for Combustion Control

Benefits

- In-situ sensor allows simultaneous determination of key combustion species concentration and temperature in harsh furnace environments
- Nonintrusive measurement is advantageous for corrosive or high particle density process environments with minimum maintenance compared to conventional extractive sampling
- Sensor capability for fast-time response allows capture of real-time process dynamics that can be used in conjunction with advanced process control techniques
- Sensor versatility provides for crosscutting industrial applications such as those associated with steel, aluminum, glass melting, and chemical operations

Applications

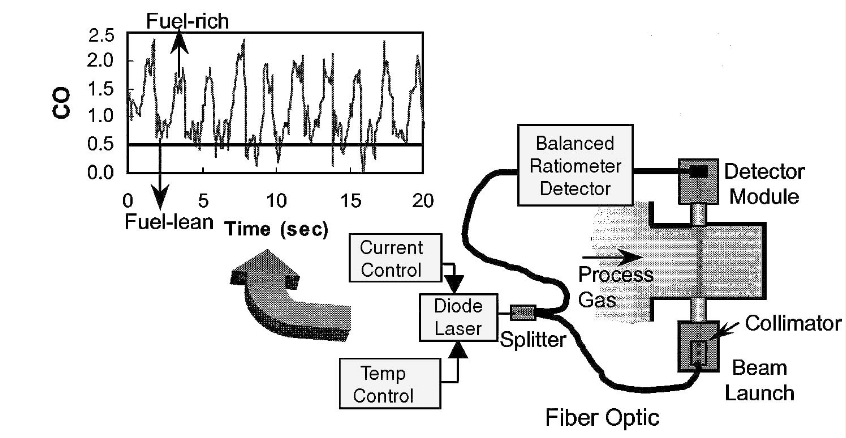
Potential applications include: (1) optimized oxygen injection to recover energy on an electric arc furnace from the carbon monoxide offgas, (2) monitoring of the combustion atmosphere in a reheat furnace for improved energy efficiency and product quality by minimizing scaling and decarbonization, and (3) monitoring and control of the excess oxygen in glass melting tanks and reheat furnaces to reduce NO_x emissions. Glass quality can be addressed by monitoring the atmosphere above the bath to maintain a reducing or oxidizing level. Sulfuric acid recovery processes benefit from process optimization controlling the oxygen level to minimize SO_2 and control NO_x, which is a pollutant and an impurity in the process. Carbon monoxide monitors the unburned hydrocarbons. Thus, many potential crosscutting applications are viable.

Tunable diode laser sensors will provide simultaneous monitoring of combustion gases and temperature for control of industrial furnaces

A sensor system based on the use of tunable diode lasers will allow in-situ determination of the concentrations of carbon monoxide, oxygen, and water vapor as well as gas temperature in harsh industrial furnaces. The chemical species targeted are key to controlling the combustion space for improved energy efficiency, reduced pollutants, and improved process quality. The nonintrusive nature of the technique is ideally suited for harsh, high-temperature environments corrosive with high particulate levels. Use of advanced telecommunication fiber optical components and rapidly tunable diode lasers enables monitoring of multiple chemical species and temperature in less than one second using only two diode lasers at a single line-of-sight measurement location.

Conventional analysis applied to combustion processes generally relies on extractive sampling techniques, which suffer from slow response times due to long sampling lines and inherent delays from the analyzers. In addition, high maintenance is required because of probe degradation from plugging or corrosion and frequent calibration. This project addresses these issues through the in-situ, nonintrusive nature of the sensor, which enables the capture of real-time furnace dynamics. The ability to monitor at key process locations makes the sensor ideally suited for use with advanced combustion control techniques. With these features, low maintenance, and autonomous operation, the sensor offers numerous economic benefits compared to conventional sensor technology.

Tunable Diode Laser Sensor



This diode laser set-up was used to demonstrate response time from a dynamic combustion process. The data obtained capture the CO variation in real time.

Project Description

Goal: Develop and demonstrate a tunable laser sensor system for monitoring multiple species and gas temperature in harsh combustion environments that can be used in conjunction with process control to improve energy efficiency, reduce pollutants, and optimize product quality.

The sensor development will employ technology from the telecommunication industry, using near-infrared light from tunable diode lasers that are fiber-optic compatible, compact, and rugged. The system will use a 763-nm diode laser for oxygen measurements; for carbon monoxide and water vapor, a newly emerging diode laser technology providing a tuning range of 10-nm near 1560-nm at microsecond rates will be used. Minimizing the number of lasers and implementing a balanced ratiometric circuitry for laser noise reduction will benefit in developing a cost-effective sensor.

The near-infrared light from the lasers is directed through fiber optics to a collimator mounted at the process measurement point, allowing the lasers and associated electronics to be stationed far from the harsh environment near the process. The light is launched across the process and received on the opposite side by a photo detector. Transmittance measurement of the light propagating across the process is collected, providing the full lineshape of the targeted absorbing species and thus allowing an absolute concentration measurement. Temperature measurements are based on using the ratio of multiple absorption transitions of the same molecule.

Before field testing, the sensor will be thoroughly evaluated and optimized on a 700-kW oxy-fuel pilot furnace capable of 1600°C flue gas temperatures. In addition, the pilot furnace is equipped with a time varying combustion technique for studying the sensor response time and particulate injection to study the effect of monitoring hot, dirty flue gas. Since the objective of the sensor is to monitor near the process exhaust or in the process itself, fluctuations in the background radiation due to glowing particulates or reflected flame flicker can limit the sensor's accuracy. These issues will be addressed to optimize the optical launch and collection system before testing at DuPont, Johns Manville, and Charter Steel. The combination of extensive pilot furnace testing and field testing on processes offering varying conditions will aid in commercializing a truly versatile sensor for numerous industrial applications.

Progress and Milestones

This project was selected through the Sensors and Controls Program FY 2000 solicitation and went under contract in May 2000. All tasks are scheduled for completion in 36 months. Key tasks that have been performed or are planned are:

- Phase I:
  a) Integration of multiple lasers, controllers, and data acquisition
  b) Laboratory testing of simultaneous species monitoring of oxygen, carbon monoxide, water vapor, and temperature
  c) Design of sensor process interface
  d) Pilot-scale testing for dynamic process conditions, effect of particulates and process radiation, and comparative measurement with conventional extractive sampling

- Continuation into Phase II:
  a) Development of industrial prototype with robust, hardened optical integration components that has been optimized on the pilot-scale furnace
  b) Planning and preparation for industrial site test
  c) Hot site testing at facilities operated by DuPont (sulfuric acid recovery), Johns Manville (glass fiber melter), and Charter steel (reheat and electric arc furnace)
  d) Selection of site for long-term demonstration with the sensor integrated into a control scheme to provide feedback control on the process fuel and oxide

Project Partners

American Air Liquide (Prime)
Chicago Research Center
Countryside, IL

Physical Sciences, Inc.
Andover, MA

Charter Steel
Saukville, WI

DuPont
Deepwater, NJ

Johns Manville
Littleton, CO

Project Information Point of Contact

William Von Drasek
American Air Liquide
5230 S. East Avenue
Countryside, IL 60525
Phone: (708) 579-7755
Fax: (708) 579-7836
Bill.VonDrasek@AirLiquide.com
www.airliquide.com/us/

S&C Program Information Point of Contact

Gideon Varga
Office of Industrial Technologies
Phone: (202) 586-0082
Fax: (202) 586-7114
Gideon.Varga@ee.doe.gov
www.oit.doe.gov/sens_cont

Office of Industrial Technologies
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, D.C. 20585
www.oit.doe.gov

OIT

January 2001